

# INDUSTRY EXPERIENCE: IMPLEMENTING TECHNOLOGY

*William B. Johnson, Ph.D.  
Chief Technology Officer  
Galaxy Scientific Corporation  
Atlanta, Georgia  
770.491.1100  
drbillj@drbillj.com*

## EXECUTIVE SUMMARY

Successful insertion of new technology into organizations requires appropriate specification, design, test, implementation, and support. Careful specification and planning help ensure that the intended user embraces and benefits from new products and procedures. This presentation addresses example considerations that contribute to tribulations and success integrating new technologies into existing organizations. The paper uses the recipe of starting with a model, adding some data, shaking it into a product, and finally supporting the product and measuring the results. The FAA's On-line Aviation Safety Inspection System (OASIS) is used as one example of a success story.

## BACKGROUND – INTRODUCTION

Since 1988 this conference has been a forum for a variety of speakers, from the distinguished gray-bearded Professors to the young hands-on aviation maintenance technician-engineers. The experience and education diversity is excellent in that it represents the broad range of personnel that come together to ensure safe, effective, and efficient airline maintenance. Most of the speakers at our annual Human Factors Symposium have one thing in common: they have made mistakes and have learned from those mistakes. Further, they are not embarrassed to teach others from their experience. Using the rationale above, the committee knows that I have made many errors over my career, thus they invited me to offer “industry experience.”

I shall couch my “industry experience” in the increasingly familiar language of human factors. I am quite sure that the human factors techniques and principles that I use as examples will be familiar to the audience. I trust that the familiarity will not “breed contempt,” but instead generate head nodding in agreement. Further, my goal is to provoke additional stories from the workshop audience that can be tied to the fundamentals of human factors.

This paper and discussion shall proceed on a continuum from general concepts to concrete examples. That continuum begins with models, discusses data, and ends with products. The stops along the way address various ways to understand the human requirements during design of equipment, software, or procedures. Whenever possible I shall make use of information developed in conjunction with the FAA Office of Aviation Medicine Human Factors in Aviation Maintenance Research Program. The formula for the paper is to start with a model, add some data, shake into a product, and finally support the product and measure the results.

## START WITH A MODEL

Models promote an understanding of a system. They help break the system into its key components, thus permitting one to act on one or more of those components. Human factors

practitioners, especially in aviation, have referred to the SHEL model (Edwards, 1972) to describe the aviation system. While words like software, hardware, environment, and liveware were somewhat useful Dr. Michael Maddox and I offer the PEAR model (Johnson, 1998) as an alternative way to think about human factors issues in aviation maintenance. The PEAR model keeps the language and concepts straightforward by considering people (P), environment (E), actions (A), and resources (R).

PEAR can ensure success in the design and implementation of products and procedures. The very first letter in the model is P, referring to a complete understanding of the “People” for whom the product is designed. In maintenance, designers must consider factors like age, strength, experience, training, motivation, and even personality of the intended user. This understanding can be accomplished in a straightforward manner - by talking to the user. Organized talking is a structured interview. Highly organized interviews become task analysis, a process that defines the requirements of the job, the worker, the equipment, and more. The term cognitive task analysis refers to the mental process and knowledge processing requirements of the worker. Another related term, business process modeling, also requires an extremely thorough task analysis of all activities related to a particular process.

Human-centered design, using PEAR, focuses on the E for environment. The environment can include the physical environment or the sociotechnical environment (Taylor et al, 1997). The former considers physical characteristics like light, temperature, and sound levels. The sociotechnical environment considers company leadership, procedures, policies, workplace norms and other less, but very important, aspects of work.

The actions (A) that a worker performs is best understood from task analyses, as described above. In considering actions, the analyst determines the nature of the tasks, whether they are serial or parallel, how the task is performed, by one or by a team, and other such factors. The analyst documents how each step is performed and how the workers communicate during task performance.

The R refers to tools, equipment, technical documentation, time, number of people and other such resources to accomplish a maintenance task in a safe, efficient, and effective manner.

The model works to derive an understanding of the system. However, each aspect of the model must be fully understood to derive maximum benefit. The next section shows specific examples.

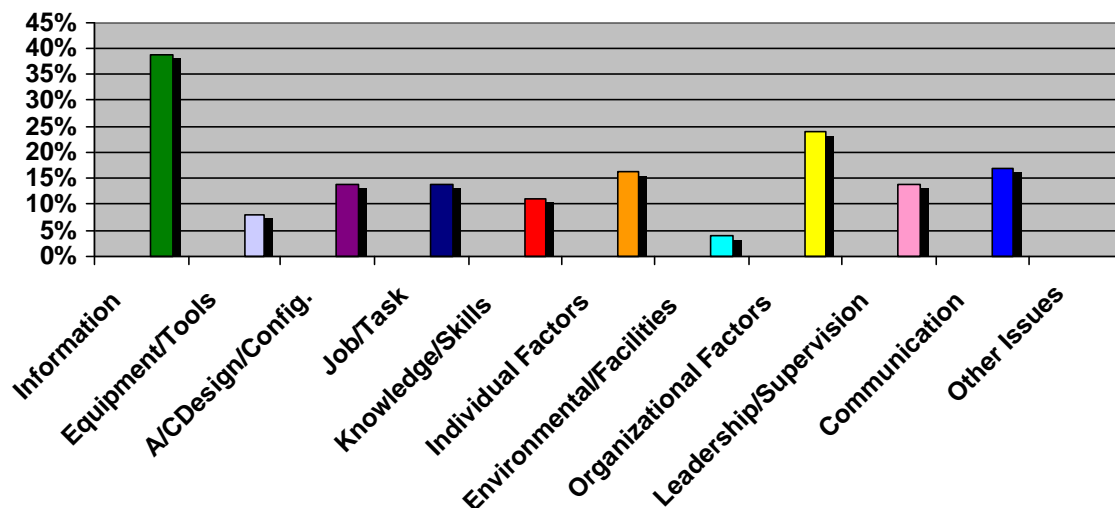
## **ADD SOME DATA**

This section of the paper is very specific and data-oriented. The data are products of two FAA research projects completed in December of 2000 (Johnson and Watson, 2001, Johnson et al., 2001). The first project studied installation error. The second project, which is ongoing, looked at the aviation maintenance physical work environment and worker rest patterns. These data represent the kind of information that must be considered during the design or modification of a product or process.

## Data on Installation Error in Heavy Maintenance

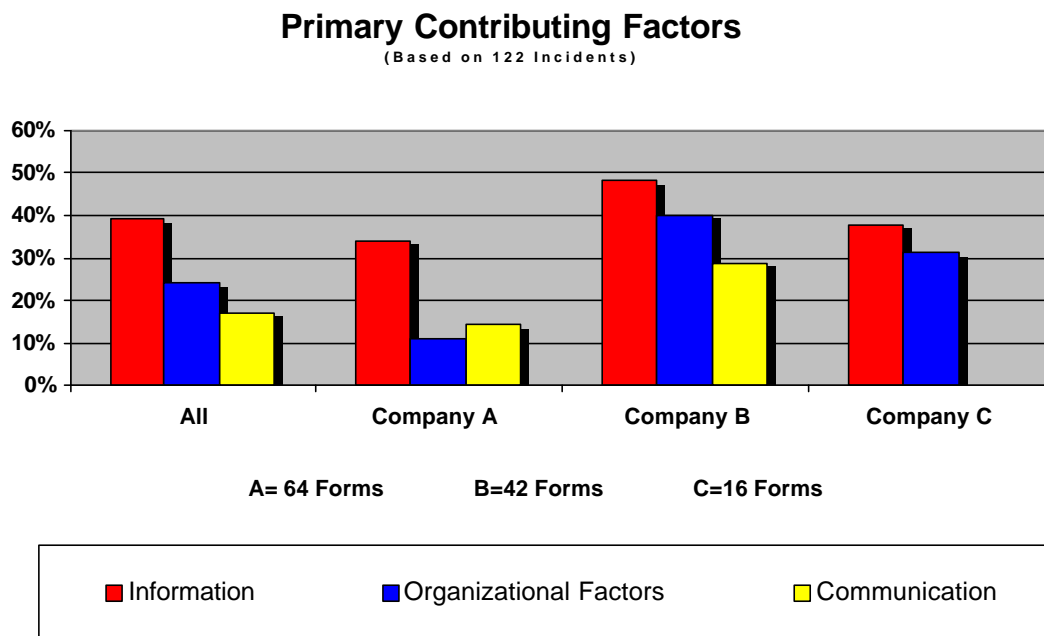
During year 2000, the FAA Human Factors research team cooperated with two airlines and one repair station to study human error. In order to delimit the size of study it focused, primarily, on errors discovered in the final stages of heavy maintenance. That included errors reported up to twenty-one days after the aircraft was returned to service. Recent studies (Rankin et al., 1998, Reason, 1998) confirmed that installation errors were particularly common and problematic. Therefore, the study looked specifically at that category of error. The data were collected following Boeing's Maintenance Error Decision Aid format, although 2 of the 3 companies modified MEDA to meet their requirements.

Figure 1 summarizes primary contributing factors data for the three participating companies. The highest ranked contributing factors are Information, Organizational Factors, and Communication. The next clustered factors include Individual Factors Skills, Technical Knowledge and Skills, Job/Task, A/C Design, and Leadership. These rankings are consistent with previous studies (Rankin et al., 1998).



**Figure 1: All Contributing Factors for Three Companies (N=125)**

Figure 2 shows the breakdown of the three primary contributing factors as they apply to the three companies. Note that Information and Organizational Factors appear as a challenge to all three companies. Communication did not appear as a challenge in any of the 16 total incidents investigated by Company C. However, past studies and the experiences of Company A and Company B qualify it as one of the three topics discussed in the final report.

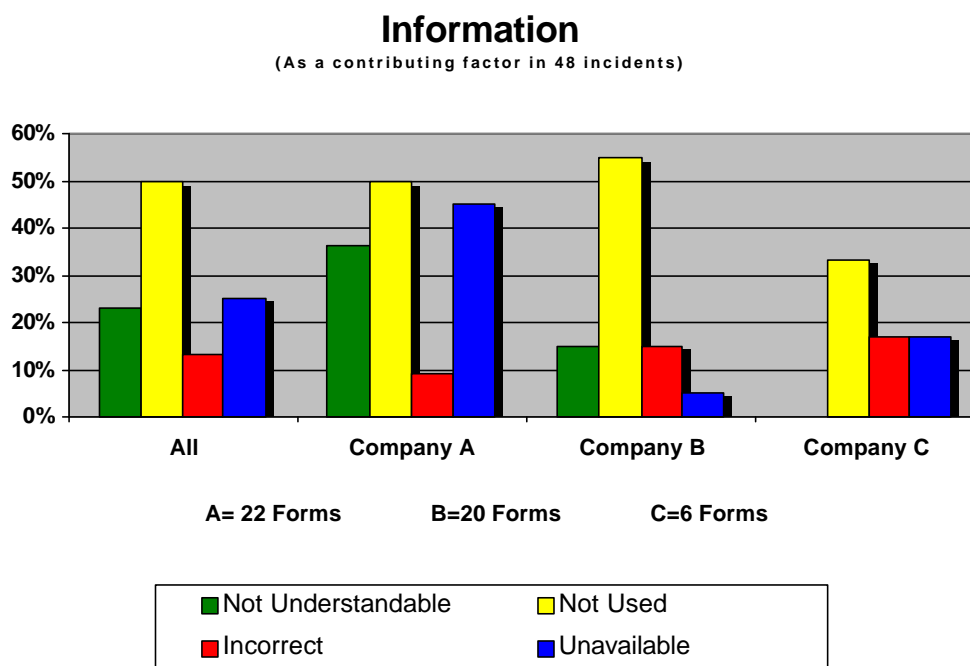


**Figure 2: Summary of Three Primary Contributing Factors**

### Analysis of the Contributing Factors

The final report for the Installation Error project is on the FAA website (Johnson and Watson, 2001) and shall not be fully described here. The report took each of the three major factors and reviewed them more closely. Figure 3 shows the break down of Information as a contributing factor. This category is a consistent problem in aviation maintenance and it is the problem that also motivated the FAA to create the On-Line Aviation Safety Inspection System, described later in this paper. In all cases, "Information not used" was the most common sub-contributing factor. In fact, 50% of the Information factors were "not used." Incorrect data was a contributing factor in a minimal number of cases. The participating companies explained that the incorrect information, most likely, referred to incorrect or incomplete write-ups by technicians.

In order to capitalize on data shown in Figures 1-3, it is helpful to revert to the PEAR model. Asking the questions about people, environment, action, and resources is absolutely necessary. A thorough task analysis and understanding of all aspects of the business process is likely to show the factors and the solutions related to the major contributing factors of error.



**Figure 3: Information as a Contributing Factor for Three Companies**

### Data on Maintenance Work Environment and Worker Rest

The second FAA year 2000 project that collected and analyzed data was related to the physiological conditions of the maintenance work environment and to worker rest patterns. The full report is available on the FAA website (Johnson et al., 2001). Ms. Jean Watson of the FAA Office of Aviation Medicine reports that study in another session of this conference. Therefore it is described very briefly here.

The research team used sophisticated measurement equipment to assess the ambient temperature, light, and sound pressure in 3 airlines in the southern and southwestern United States during July through September. Approximately 100 working mechanic/engineers wore the measurement equipment, while at work, for two-week periods. In addition, workers wore a device, called an Actiwatch, that measured rest and sleep patterns for two-week periods. Workers wore the sleep monitoring devices seven days a week for twenty-four hour periods.

The devices confirmed that work conditions were hot, noisy, and not light enough. However, observations showed that the companies were doing a very good job compensating for sub optimal conditions with portable cooling units, liquids for hydration, hearing protection, ancillary lighting equipment, and other such equipment and procedures. There are plenty of opportunities to improve conditions. The accurate data, combined with PEAR, can help decide the highest payoff areas.

The sleep data were the most alarming data collected. Across the three companies, mixing all shifts, experience levels, and ages, maintenance personnel are not getting enough sleep. The devices showed that the average quality sleep time of the participants was just over five hours. The time in bed, falling asleep and waking up, totals about 5 hours and 45 minutes, on the average. Experts agree that humans need about 8 hours of sleep. This study shows that the industry must take steps to re-educate the workforce regarding proper sleep.

## SHAKE THE DATA INTO A PRODUCT

Information from PEAR, from task analyses, from error investigation reports, from research programs, and from other sources helps to identify the need for new or revised products and procedures. This section uses an example of a successful FAA project that used human-centered design, task analyses, and business process modeling to design, develop, deliver, and support a new technology for FAA Aviation Safety Inspectors. The product/program is the On-line-Aviation Safety Inspection System (OASIS).

In the early nineties the US General Accounting Office (GAO), a government oversight agency, strongly criticized the FAA Flight Standards Service for the overall quality of their safety data. The data was not reported in a timely fashion and the data itself was inaccurate and often incorrect. At the same time the FAA was recognizing the need for increased and stricter industry inspection. The challenge was further complicated by a shortage of qualified inspectors. About that time, the FAA Office of Aviation Medicine was experimenting with stylus input portable computers for airline inspectors. The FAA Administrator heard about the Aviation Medicine research project and suggested a “Rapid Deployment” of pen-based computers for all 3000 Aviation Safety Inspectors. The Office of Aviation Medicine, with members of the research team, convinced the Administrator that rapid deployment of such a technology was certain to fail. Instead, the team proposed a human-centered design, a thorough task analysis, and a phased development and deployment schedule. The team had not yet invented the term “PEAR”, thus the FAA Administrator was spared such a lecture. However, FAA agreed that the design and deployment of such a major change should be based on human factors design principles.

For the first eighteen months of the OASIS program, starting in 1994, the team conducted a thorough task analysis to define the daily operational requirements of the Aviation Safety Inspector (ASI) (Johnson and Layton, 1994). The team traveled with inspectors, learned about the job and the environment, and tested a variety of prototype software concepts and portable stylus-input computers. The team traveled from Alaska to Puerto Rico to characterize the work environmental conditions and the nature of the aviation inspection process. At the same time, the team began to understand the sociotechnical (aka. internal politics) nature of the FAA field offices and FAA Headquarters. Figure 4 shows two FAA inspectors using an OASIS prototype to test stylus-input computers early in the development and specification phase of the project.



**Figure 4: FAA Inspectors with Beta Versions of OASIS**

An important result of the task analysis was an overwhelming grass roots field-level support for the concept of applying new technology to the ASI's job. It became clear that software design, testing, and support were the important issues. Selection of the hardware was relatively easy. Inspectors were not impressed with slow stylus-input portable computers. Instead they created specifications for powerful laptop computers that used docking stations for quick connection to the FAA's evolving area network.

When a new technology is implemented it cannot ignore the legacy systems. In fact, conventional wisdom now defines "Legacy System" as "the one that works." OASIS had to communicate with a variety of legacy databases, some of which were nearly twenty years old, running on antiquated mainframes. At the same time, OASIS was designed for the necessary forward compatibility for modern client-server systems. The result is that users had only one interface to the old and the new databases.

Another caution centers on compatibility with existing local area networks. During the early task analysis and initial fielding, it became clear that each FAA field office had its own unique network characteristics. In order for OASIS to gain acceptance, it had to adapt to the hardware and software requirements of the existing systems. That challenge is quite common when any new technology system is installed. Developers and implementers must be prepared for the differences in hardware systems, knowledge levels, and attitudes that exist among various geographical locations of the same company. Today, as more systems are designed for web-browser capability, portions of the software geographical standardization are more manageable.

## **SUPPORT THE PRODUCT AND MEASURE THE RESULTS**

Even the best products and systems in the world need excellent customer support. The large customer support departments of Boeing, Airbus, and the large engine manufacturers are evidence of that. In the same way, new technologies need extensive customer support. In the case of OASIS, that support began with coordination with each local area network administrator to ensure compatibility between the existing system and the new OASIS laptops. The systems were delivered and accompanied, immediately, by 4-5 days of stand-up training. Each inspector brought their new OASIS system to class with them for four days and then used the system on-the-job with training personnel present.

The stand-up training was supplemented with a customer support hot line available 60 hours per week. There is also a website to report problems and obtain information. The website has a variety of training available, as shown in Figure 5. When implementing the new OASIS technology the developers were cognizant that bad news travels fast in the FAA inspector circles. For that reason each field office implementation had to be successful or the subsequent implementations would be at an extreme disadvantage. That example applies to implementation of technology at various sites of an airline.

The FAA asked the developer to assess the financial impact of the new OASIS system. The developer conducted a "Utility Analysis" for the calculation. This type of analysis interviews users to ask them about their job before and after the new technology was introduced. The large-scale study showed that FAA Aviation Safety Inspectors estimated a timesavings of 20% on all their inspection tasks. This number confirmed FAA opinion on the extremely fast return on the OASIS investment (Hastings, et al., 2000).



New technology must evolve. For OASIS that means movement towards browser-based interfaces and operations via the web. Further, OASIS is moving toward the small handheld wireless systems using the browser interface. In the years since OASIS started the rate of change in database structures, interface capabilities, display and communications hardware, and other related technologies is truly amazing. The only way that systems like OASIS shall continue, with extensive efficient and effective field use, is by the developers constant attention to the evolving user requirements and expectations.



**Figure 5: A Web-based Offering of OASIS Refresher Training for Inspectors**

## SUMMARY

There is no guarantee to success when implementing new technologies. The challenges can be overwhelming. This paper has offered a few ways to reduce the risk. First of all, think PEAR and consider the advance task analyses necessary to understand the person, the work environment, the actions performed, and the required resources. Then use the formula, start with a model, add some data, shake the data into a product or process, and finally support the product and measure the results.



## REFERENCES

1. Edwards, E. (1972). Man and machine: Systems for safety. In Proceedings of the British Airline Pilots Association Technical Symposium (pp 21-36). London, UK: British Airline Pilots Association.
2. Hastings, P.A., Merriken, M. and Johnson, W.B. (2000). An analysis of the costs and benefits of a system for FAA safety inspectors. *International Journal of Industrial Ergonomics*, 26 (2000), 231-248.
3. Johnson, W.B. (1998). Past, present, and future of human factors in aviation. *Proceedings of the 12<sup>th</sup> Symposium on Human Factors in Aviation Maintenance*. Joint meeting of CAA, FAA, and Transport Canada at Gatwick Airport, UK, 10-12 March 1998.
4. Johnson, W.B., Mason, F., Hall, S., and Watson, J. (2001). *Evaluation of Aviation Maintenance Working Environments, Fatigue, and Human Performance*. Washington, DC: Federal Aviation Administration Office of Aviation Medicine. <http://hfskyway.faa.gov>.
5. Johnson, W.B. and Layton, C.F. (1994). Design, implementation and evaluation of a performance enhancement system for aviation safety inspectors. *Proceedings of 8th Human Factors in Aviation Maintenance and Inspection Conference*. Washington, DC: Federal Aviation Administration Office of Aviation Medicine.
6. Johnson, W.B. and Watson, J. (2001). *Installation Error in Airline Maintenance*. Washington, DC: Federal Aviation Administration Office of Aviation Medicine. <http://hfskyway.faa.gov>.
7. Rankin, W.L., Allen, J.P., Jr., and Sargent, R.A. (1998). Maintenance error decision aid: progress report. *The 11<sup>th</sup> Annual FAA Conference on Aviation Maintenance and Inspection*. Washington, DC: FAA 1998. (<http://hfskyway.faa.gov>).
8. Reason, James (1998). Approaches to controlling maintenance error. *The 11<sup>th</sup> Annual FAA Conference on Aviation Maintenance and Inspection*. FAA: Washington, DC. 1998. (<http://hfskyway.faa.gov>).
9. Taylor, J.C., Robertson, M.M., & Choi, S.W. (1997). "Empirical Results of CRM Training for Aviation Maintenance Technicians." In Proceedings of the Ninth International Symposium on Aviation Psychology. Columbus, Ohio, The Ohio State University.
10. Watson, J. and Johnson, W.B. (2001). Assessing aviation maintenance work environments and worker rest. *Proceedings of the 15<sup>th</sup> Symposium on Human Factors in Aviation Maintenance*. Joint meeting of CAA, FAA, and Transport Canada at the Brewery, London, UK, 27-29 March 2001.